THE ENVIRONMENTAL IMPLICATIONS OF ROAD SALTING IN NOVA SCOTIA

Nova Scotia

Department of the Environment

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Department of Transportation and Communications

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Jointly Prepared By

Nova Scotia Department of the Environment

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1. CONCLUSIONS

1) Nearly 250,000 tonnes of road salt and 90,000 cubic metres (161,000 tonnes) of sand/salt mixtures were applied to roads in Nova Scotia as part of the 1988-89 winter maintenance program. Both figures are up from previous years and represent a proportionally high usage compared to most other Canadian provinces.

2) The N. S. Dept. of Transportation & Communications has ice control and sanding policies in place and yearly training sessions for its operators that incorporate the "sensible salting" concept.

3) While all of the salt in storage is housed indoors and most on impermeable asphalt or concrete pads, many of the sand/salt mixtures are left outside unprotected and thus are subject to leaching.

4) Damage claims relating to contamination of wells from road salting amounted to over $300,000 last year. It is estimated that possibly 20% of all wells in Nova Scotia contain sodium and chloride levels above natural background levels. This figure is considerably higher for wells within 100 feet of roadways.

5) Contamination of surface water bodies from road salting does not appear to be a problem in Nova Scotia. Any contamination that does occur is seasonal, however, a few lake studies have shown chloride levels to be increasing each year possibly leading to lake eutrophication.

6) The impact on roadside trees and plants from road salting appears to be minimal. Salt spray probably causes what little damage there is.

7) Vehicle corrosion due to road salting probably costs Nova Scotia car owners around $200 per year in vehicle depreciation.

8) Deterioration of roads, bridges and other reinforced concrete structures is widespread across the province - a great deal of it due to road salting. Annual expenditures on concrete bridge repairs alone amount to over $1.9 million and only represent about one-third of the total repairs that are required.

9) The benefits of road salting outweigh the costs so it is unlikely that the use of road salt will be discontinued in the near future. Most alternatives available are either impractical or uneconomical thus attention must be given to minimizing salt usage and improving storage and handling techniques.

2. RECOMMENDATIONS

1) All necessary steps should be taken to minimize the use of salt without sacrificing driving conditions. Discussions with highway personnel have indicated that a 25% reduction may be possible. These steps should include, but are not limited to, the following:

- use of ground speed controlled spreaders and frequent calibration so that proper application rates are maintained and excess salt is not applied when the truck is stopped or moving slowly.
- strict adherence to ice control and sanding policies
- spreading of salt in windrows at the centre of the highway
- use of accurate weather forecasts geared to road conditions for the timely application of salt.
- greater reliance on plowing to keep the roads bare rather than excessive salting
- timely repairing of cracked and rough pavements which are difficult to plow and require additional amounts of salt to achieve bare pavement
- better accounting of the amounts of salt used and where
- greater awareness on the part of the operators of the environmental impacts of road salt and associated costs

2) Stockpiles of sand/salt mixtures should not be left unprotected. They should be stored indoors if possible or at least covered up.

3) Greater care should be taken to reduce salt spillage during loading and mixing operations. Mixing and loading should be done indoors where possible or on an impermeable base. Trucks should not be overloaded so that they do not spill

part of their load when leaving the yard.

4) Salt should not be considered as the only answer to road deicing. Other products should be researched and tested periodically in the hope of finding a suitable alternative.

5) Road salt usage should be monitored more closely to determine how much salt is necessary. For example, an area could be selected that is known to be environmentally sensitive and a program established to monitor the amount of salt used and both its useful and harmful effects.

6) An information booklet or brochure should be prepared for public dissemination that will increase awareness of the benefits and costs of road salting.

3. INTRODUCTION

Highway safety is one of the major priorities of any winter road maintenance program. Thus the removal of snow and ice from the province's roads and highways as quickly as possible is considered essential in creating safe driving conditions. To achieve "bare pavement" conditions requires the use of highway deicers such as road salt. The maritime climate in Nova Scotia with its rapidly fluctuating temperatures and frequent winter storms makes road salting a large component of winter road maintenance. Approximately a quarter of a million tonnes of road salt (sodium chloride) were applied to Nova Scotia's highways last year with each kilometre of highway receiving on average about 20 tonnes of salt. About four million tonnes of road salt are applied to Canadian roads each year (Spurgeon, 1989).

Such use of road salt is not without harmful effects to the surrounding environment. In general, it contaminates groundwater supplies which many people depend upon for drinking water as well as nearby lakes, streams and ponds. It contaminates soil and damages crops, orchards, trees and other roadside vegetation. It also damages roads, bridges and other reinforced concrete structures such as parking garages and enhances the corrosion of vehicles. Thus road salting becomes a paradoxical issue: eliminate the use of salt on our roads and jeopardize driver safety or continue salting and risk serious and costly damage to our environment.

A great deal of attention has been given to road salting practices, impacts and alternatives over the past twenty years or so resulting in an extensive literature base. It is not the purpose of this report to provide a detailed review of the literature or an in - depth study of the topic of road salting. Rather, this report is intended to give a brief look at the environmental implications of road salting from a Nova Scotia perspective in an attempt to gain an understanding of this important issue.

In addition to outlining some of the environmental problems, the report also reviews current road salting practices in Nova Scotia and discusses possible measures that might help minimize or alleviate the environmental impact. The road salting figures given in this report are for rural municipalities and counties only, as serviced by the N.S. Department of Transportation & Communications. Coverage of municipal road salting would require surveys of individual towns and cities and is outside the scope of this report.

4. ROAD SALTING IN NOVA SCOTIA - MATERIALS AND OPERATIONS

4.1 Deicing Chemicals and Abrasives

Safe driving conditions and the control of snow and ice on roads is achieved through plowing and the use of chemical deicers and abrasives. The primary purpose of deicing chemicals is to lower the freezing point of water and break the bond between snow and ice and the pavement; abrasives are used to increase skid resistance and provide traction. The deicer is applied at the beginning of a snowfall to form a brine which spreads across the pavement and prevents the bonding of snow and ice and the ensuing buildup into snow pack. The loosened material is plowed off and subsequent applications of salt maintain the brine on the road surface and prevents refreezing (Cross, 1980). Abrasives are normally applied to unpaved roads after a snowfall. In some areas on paved roads, such as in areas with known well contamination problems from road salting, abrasives are applied in the same manner as salt.

Although there are a variety of chemically-based deicers available, sodium chloride (NaCl) and calcium chloride ($CaCl_2$) are most commonly used in North America (Keyser, 1973; Hanley, 1979). Sodium chloride, occurring naturally as 94 - 97% pure rock salt, draws in heat and dissolves slowly - boring its way through the ice surface to weaken the ice to pavement bond. It is effective at temperatures down to about -12 ^{o}C (10 ^{o}F). Calcium chloride, commercially available as flakes or pellets, produces rapid melting since it dissolves very quickly in water.

However, because it attracts moisture it produces a slippery, wet surface after melting. An advantage of calcium chloride is that it can be used at temperatures down to -34 oC (-30 oF). Sodium chloride is by far the most widely used deicer since it is two to three times cheaper than calcium chloride and much easier to store and handle. Abrasives are granular material such as sand, slag or cinders applied on trouble spots and at low temperatures to provide traction. They are usually mixed with small amounts of deicing chemicals to keep them from freezing and to help the particles embed themselves into the ice surface and prevent being swept away by traffic and wind. The suitability of deicing chemicals and abrasives is summarized in Table 1 below.

Table 1. SUITABILITY OF CHEMICALS AND ABRASIVES (Keyser, 1973)

Material	Main Purpose	Suitability for Use	Principal Advantages	Principal Disadvantages
Sodium chloride	Melt snow and ice	Very effective above 25 F; effective between 15 and 25 F; marginal between 10 and 15 F; not effective below 10 F	Provides immediate traction; salt particles bore, penetrate, and undercut ice layer; freezes dry on pavement surfaces; low cost	Low rate of solution; useless at very low temperatures
Calcium chloride	Melt snow and ice	Normally used below 10 F; effective to -20 F; marginal between -20 and -30 F; not effective below -30 F	High rate of solution; liberates heat when going into solution; effective at low temperatures	Higher cost; melting action takes place at ice surface; pavement remains wet
Mixtures of $CaCl_2$ and NaCl	Melt snow and ice	In cold weather (to 0 F) when snow and ice must be melted in a short time	High rate of solution; effective at low temperature; more stable on the road	Higher cost; pavement wet longer than with NaCl
Mixtures of abrasives and salt	Increase sliding friction immediately	In very cold weather when salt is not effective or where clean plowing is impossible if immediate protection is necessary	Free flowing material; no freezing of stockpiles; abrasives more stable on road; quick anchoring of abrasive to road; skid resistance improved immediately	Creates spring clean-up problems; does not remove ice or snow, causing slipperiness; may damage vehicles traveling at high speeds
Abrasives	Increase sliding friction immediately		Skid resistance immediately improved	As above; easily brushed off road by tires

In Nova Scotia, road deicing is accomplished through the use of sodium chloride in the form of rock salt, most of which is supplied by the Canadian Salt Company mine in Pugwash. Approximately 100 ppm (0.01%) of sodium ferrocyanide (YPS, yellow prussiate of soda) is added to the salt as an anti-caking agent. Calcium chloride is only used for special applications such as thawing catch basins and storm drains. Sand, mixed with about 5 to 10% salt to keep it friable, is used for abrasives treatment. Raw salt costs approximately $25/tonne; sand costs approximately $12/tonne.

4.2 Ice Control and Sanding Policies

The demand that roads be safe and usable at all times, i.e. June driving conditions in January, created a "bare pavement" policy adopted by practically all transportation departments in the snow belt regions in Canada and the U.S. that greatly increased the use of deicing salts (Struzeski, 1971). In 1972, the Salt Institute initiated a "Sensible Salting" concept which emphasizes use of the least amount of salt necessary, calibration of salt spreaders, use of automatic controls to properly measure applications and proper storage (Salt Institute, 1976). The N.S. Dept. of Transportation & Communications has snow and ice control policies and training sessions which incorporate the "Sensible Salting" concept.

As part of the ice control policy, roads are assigned a level of service which can be expected within a reasonable length of time after a storm:

Ice Control Policy

LEVEL I - BARE PAVEMENT. All 100 series and selected high volume highways. Salt will be applied at beginning of storm and after storm if required. Salt may be applied during a storm depending on weather and road conditions.

LEVEL II - CENTRE STRIP BARE 2.5m - 5m. Selected arterial, collector and local roads. Salt will be applied at beginning of storm and after storm if required.

LEVEL III - CENTRE STRIP BARE 1m - 2.5m. Some collectors and selected local roads. Salt will be applied only after the storm.

LEVEL IV - SANDING. Remaining paved and gravel roads. Sand will be applied to hills, turns, intersections and railway crossings. Level areas will not normally be sanded unless severe slippery conditions exist.

Salt is not applied if the snow cover is over 5 cm deep or if the temperature is below -10 °C (day) or -7 °C (night). Roads that have been designated for sanding and where salting has been discontinued for environmental reasons are also accorded three levels of service under a sanding policy:

Sanding Policy

LEVEL I - Selected arterial collector and local roads where salting Level I and II have been discontinued. Sanding may take place at the beginning of a storm and is to be discontinued after 2 - 3 cm of snowfall accumulation. Sanding will not normally take place during snowfall. Sanding will be carried out after snowfall only if required.

LEVEL II - Low volume collector and local roads where Level III salting has been discontinued. Sanding after snowfall only.

LEVEL III - Remaining paved and gravelled roads. Sand will be applied when required to hills, turns, intersections and railway crossings. Level areas will not be sanded unless severe slippery conditions exist.

Also included in the ice control and sanding policies are recommended application rates to control the amount of salt and sand/salt mixtures used as outlined below:

Maximum Recommended Application Rates Per Km (2-lane roads)

	Level I	Level II	Level III
SALTING	125 kg/km	110 kg/km	85 kg/km
SANDING	800 kg/km*	800 kg/km*	500 kg/km**

* sand to be applied on each lane at half rate of 400 kg/km
** sand centre strip only (one pass 8 - 12 ft. wide)

The N. S. Dept. of Transportation & Communications has a Snow & Ice Control Operators Manual to familiarize its operators with snow and ice control policies, equipment and methods. The manual covers the procedures to be followed, servicing and calibration of equipment, and reporting of salt and sand amounts applied. Special training sessions are held for equipment operators each fall and throughout the winter as needed to review the snow and ice control policies and methods. They are also made aware of the costs and environmental problems associated with excessive salt applications.

4.3 Provincial Usage

In 1988-89, almost 250,000 tonnes of road salt and 90,000 cubic metres (161,000 tonnes) of sand/salt mixtures were spread on Nova Scotia's roads at a total cost of $22.6 million. This accounts for over half the cost of the total winter maintenance program (Figure 1) and represents a cost increase of about $3.3 million from the year before. Each kilometre of road in the province received an average of 19.3 tonnes of salt although the amount applied on 100 series and high volume highways could be double that figure.

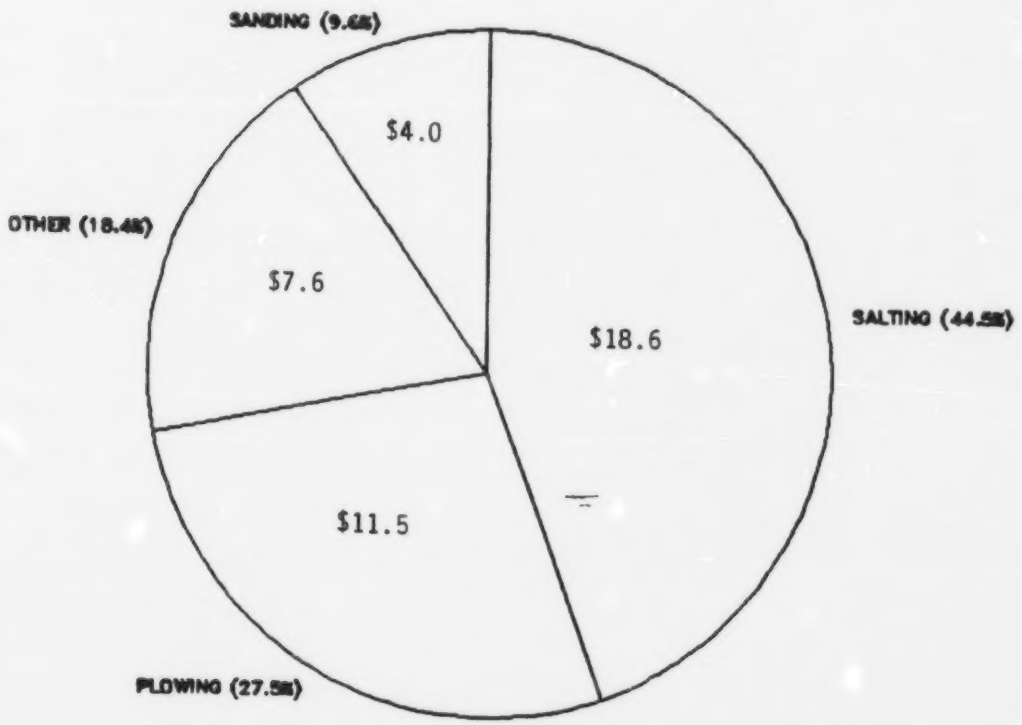
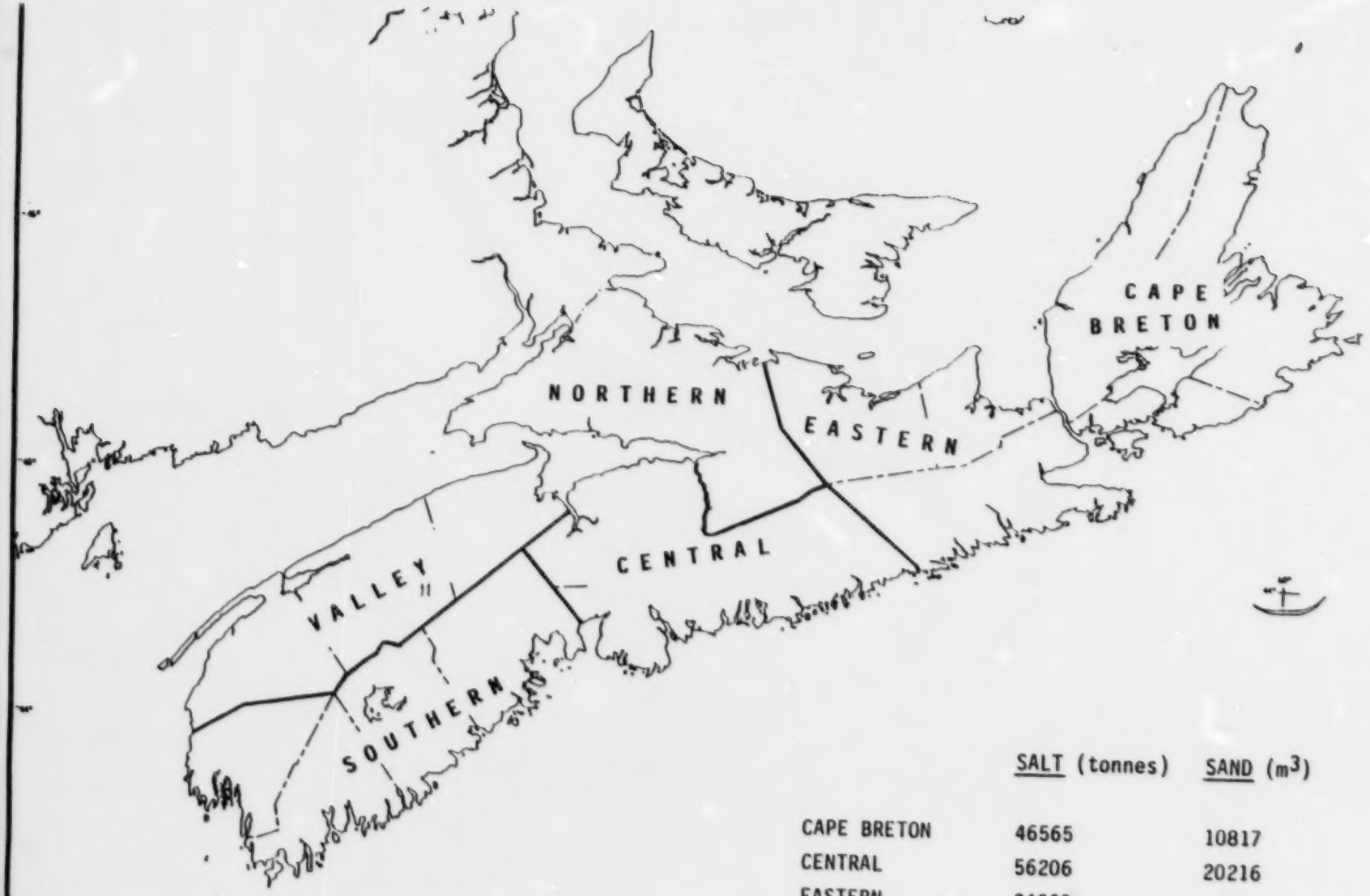


FIGURE 1: 1988-89 WINTER MAINTENANCE COSTS (millions of dollars)

Figure 2 shows the breakdown of the province into six geographic regions and the corresponding amounts of salt and sand used in each region during 1988-89. A more detailed summary of salt and sand/salt usage is given in Table 2 which gives the number of approved salting and sanding kilometres in each region, the total number of tonnes (salt) and cubic metres (sand) applied and the corresponding yearly application rates in tonnes/km and cubic metres/km respectively.

Table 2. 1988-89 SUMMARY OF SALT AND SAND/SALT USAGE IN N. S.

	SALTING			SANDING		
	kms	tonnes	t/km	kms	m^3	m^3/km
CAPE BRETON	2478.7	46565	18.8	1930.9	10817	5.6
CENTRAL	2373.5	56206	23.7	1516.5	20216	13.3
EASTERN	1938.4	34669	17.9	1637.1	9890	6.0
NORTHERN	2052.4	45315	22.1	1614.3	9382	5.8
SOUTHERN	2135.3	27493	12.9	1758.5	10001	5.7
VALLEY	1712.6	35233	20.6	1815.7	26309	14.5
total	12690.9	245481	19.3	10273.0	86615	8.4



	SALT (tonnes)	SAND (m^3)
CAPE BRETON	46565	10817
CENTRAL	56206	20216
EASTERN	34669	9890
NORTHERN	45315	9392
SOUTHERN	27493	10001
VALLEY	35233	26309

Fig. 2 Breakdown of Salt and Sand Usage By Region

Figure 3 shows the Central and Northern regions to be the greatest salt users at 23.7 and 22.1 tonnes/km respectively. This is not surprising since the Central region contains the major population centres of Halifax-Dartmouth and Suburbs and the main corridor to the province is in the Northern region - thus the demand for salt is the greatest. The Southern region used the least amount of salt averaging 12.9 tonnes/km. A similar graph for sand usage (Figure 4) shows the Valley and Central regions to be the greatest users of sand/salt mixtures. Cape Breton used the least amount of sand although the remaining regions are just marginally above Cape Breton's output.

4.4 Salt Storage Facilities

Bulk storage of salt and sand/salt mixtures in the form of stockpiles at various depots across the province offers maximum availability and convenience. In the past, many of these stockpiles were kept outdoors with no form of protection from wind and rain. Due to the environmental problems caused by leaching of salt from unprotected salt and sand/salt stockpiles, more attention has been given in recent years to ensuring that such stockpiles are fully enclosed or suitably covered and placed on asphalt or concrete pads.

Enclosed structures are preferred since they: (1) abate contamination of nearby ground and surface waters by excess salt runoff (2) improve aesthetics in the local area (3) prevent formation of lumps and frozen crusts (4) eliminate heavy, caked

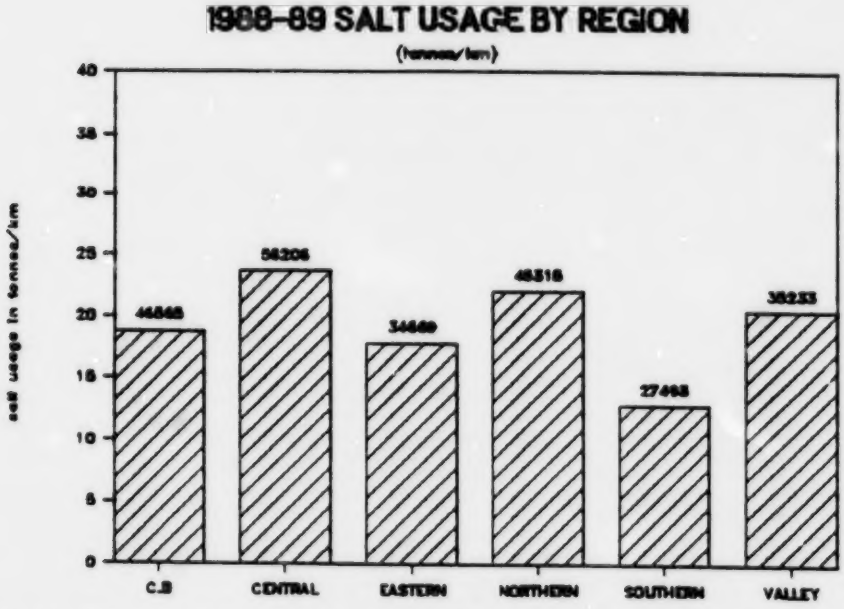


FIGURE 3: BAR GRAPH SHOWING REGIONAL SALT USAGE IN TONNES PER KM (total # of tonnes applied is given above each bar)

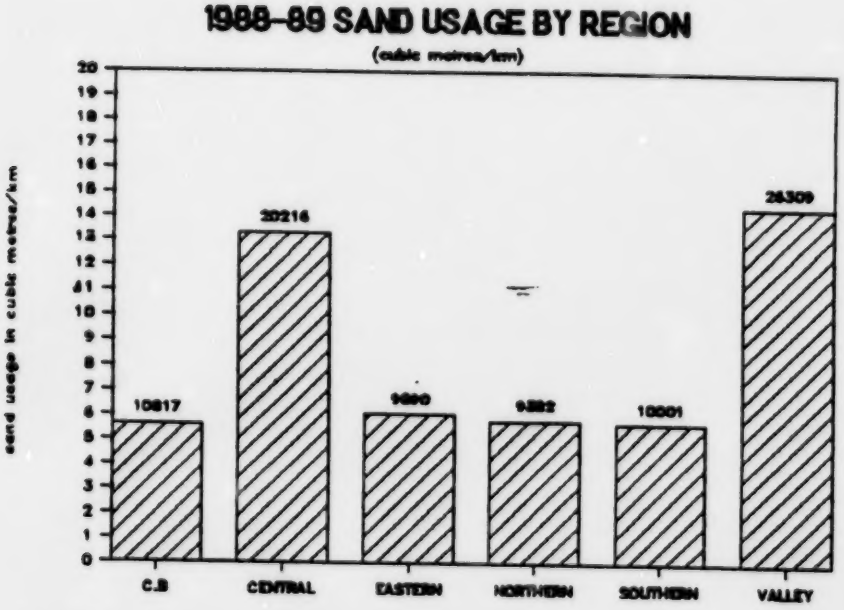


FIGURE 4: BAR GRAPH SHOWING REGIONAL SAND USAGE IN CUBIC METRES PER KM (total # of cubic metres given above each bar)

salt in the pile thereby facilitating easier handling by mechanical equipment and (5) enable better control over stored materials and more efficient loading and unloading (Struzeski, 1971). Of the various structures that have been tried, dome-type structures such as the one shown in Figure 5 have proven to be the most practical and satisfactory.

In response to a study of salt storage facilities in Nova Scotia (Cross, 1978a), all of the Dept. of Transportation & Communications salt stockpiles are now covered and most have asphalt or concrete bases. Across the province there are 65 salt storage buildings capable of storing 75,000 tonnes of material. These are comprised of the following types of structures:

24 domes (37%)
24 silos (37%)
17 sheds (26%)

Only nine stockpiles of sand/salt mixtures are stored in buildings, the remaining forty one stockpiles being stored outside and most on gravel pads.

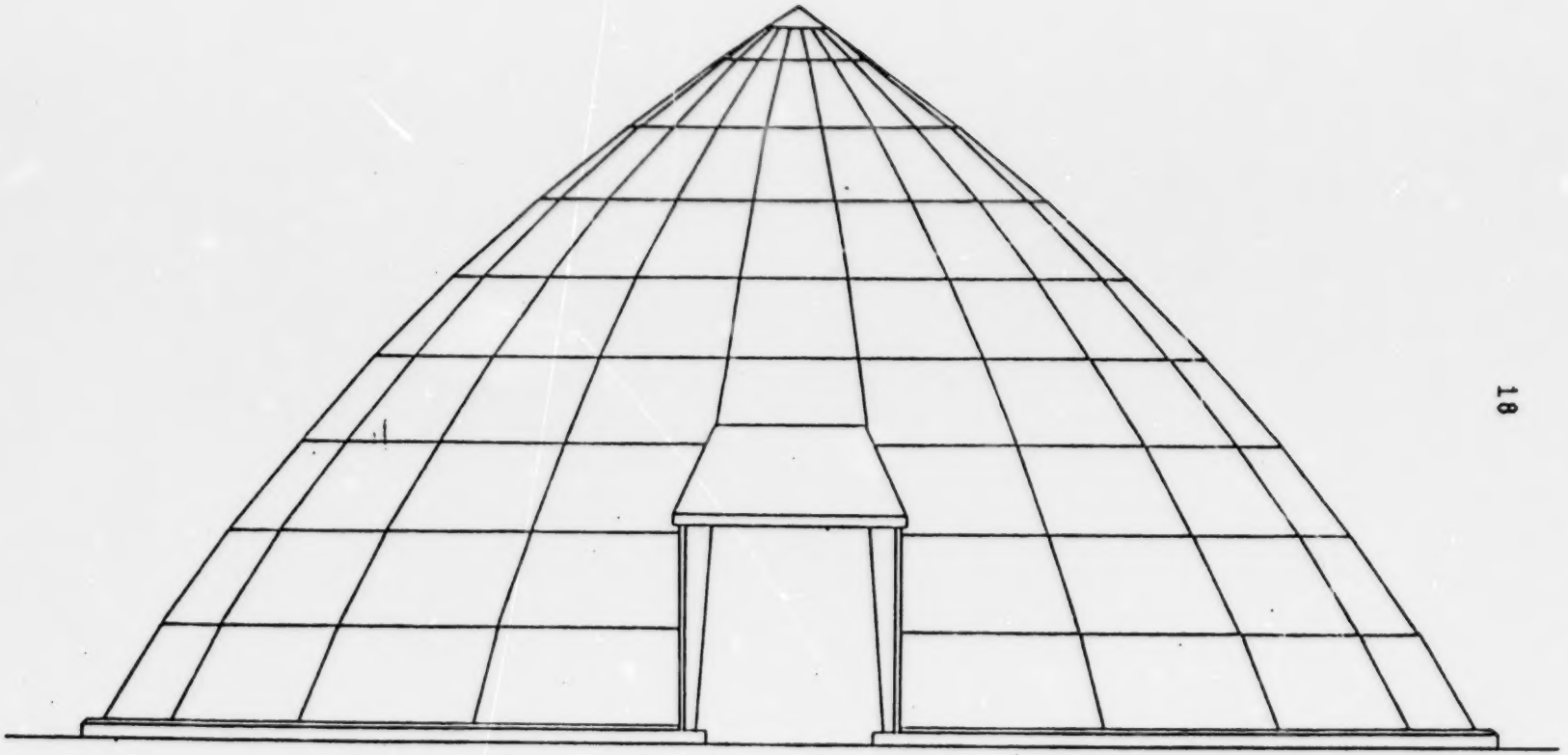


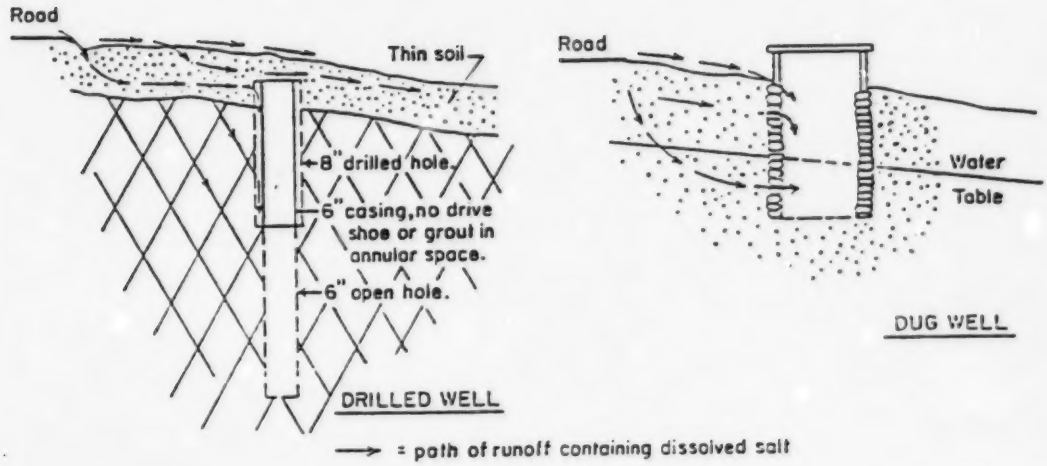
FIGURE 5: FITZPATRICK TYPE DOME (after Ontario M.O.E., 1978)

5. ENVIRONMENTAL IMPACTS OF ROAD SALTING

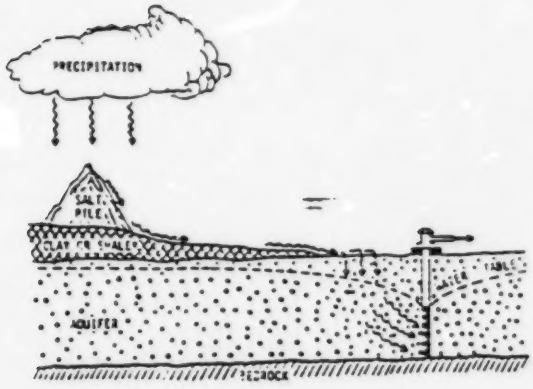
All of the salt applied during deicing activities does not stay on the road. Road runoff, the bounce of rock salt applied from the back of moving trucks, rotary spreaders, traffic movement and snow plowing redistribute salt and salt-laden snow onto roadsides. Salt in solution may then be carried directly into streams, lakes and ponds or it may infiltrate into the soil and groundwater system where it affects roadside vegetation and wells. The salt that remains on the road is left to attack bridge decks and other road structures or is lapped up by traffic where it greatly enhances vehicle corrosion. Another problem lies with contaminated runoff from unprotected salt and sand/salt stockpiles.

5.1 Groundwater Contamination

Many wells in Nova Scotia are contaminated each year by road salt entering the groundwater aquifers that supply our drinking water. Dissolved sodium and chloride ions in road runoff, meltwater from snow at the sides of roads and leachate from unprotected salt and sand/salt piles infiltrate the surficial material and into the groundwater system, as shown in Figure 6. A migratory salt plume or lens forms beneath the source and gradually moves through the groundwater system - diluting as it spreads away from the source. However, groundwater flow rates are very slow and it may take months or even years for salt to "flush" through the system even when the source has been removed.



(A)



(B)

FIGURE 6: GROUNDWATER CONTAMINATION BY RUNOFF FROM (A) A ROAD SURFACE (after Cross, 1978a) AND (B) A SALT STOCKPILE (after Walker and Wood, 1973).

A recent study in Quebec (Gelinas and Locat, 1988) found that the chloride levels detected in roadside wells were the results of salt that had been spread three years before. A study in the Halifax area (Cross, 1980) estimated a period of ten years for the groundwater aquifer to return to background chloride levels.

The Guidelines for Canadian Drinking Water Quality (Health and Welfare Canada, 1987) recommend a maximum acceptable concentration for chloride of 250 mg/L based on aesthetic objectives for taste and corrosion. Chloride levels in the body are well regulated, however, concentrations in drinking water in excess of 1000 mg/L may be physiologically unsafe (Lehr et al., 1980). While no guideline has been set for sodium, too much salt generally contributes to hypertension, poor circulation and stress on internal organs (National Research Council, 1977). The American Heart Association has recommended a sodium intake of less than 500 mg per day for people on sodium-restricted diets, i.e. a drinking water limit of 20 mg/L. However, it should be kept in mind that the intake of sodium from drinking water is only a small portion of that consumed in food. For example, milk contains about 520 mg/L of sodium and tomato soup about 3900 mg/L. In many cases, the natural background concentration of sodium in groundwater exceeds 20 mg/L. Nevertheless, it is estimated that 18% of adult Canadians suffer from hypertension (Spurgeon, 1989), and while the link between sodium and these types of health problems are still under study, long term use of groundwater with elevated sodium levels due to road salting may

be a potentially serious problem and can not be overlooked.

A survey of 100 randomly selected wells along major highways in Maine (Hutchinson, 1970) revealed that one-fifth of the wells exceeded the water quality guidelines for chloride while many others were close to the limit. A survey of private wells along highways in York County, Ontario (Joy, 1979) indicated that one out of every 20 wells tested had sodium concentrations greater than 250 mg/L while over half had greater than 20 mg/L. It is impossible to determine the extent of road salt contamination of wells in Nova Scotia without sampling every well. A review of base-line well water quality for the province from N. S. Dept. of the Environment records from the past few years suggests that about 20% contain chloride levels greater than 50 mg/L while approximately 3% exceed the drinking water guideline of 250 mg/L. If a value of 50 mg/L is taken as a typical background chloride concentration in Nova Scotia (Cross, 1978b), then it is likely that many wells contain elevated chloride levels.

While road salting is not the only source of chloride in wells, it has to be considered as a major contributor - especially for wells located within 100 feet of roadways. The study by Cross (1980) in the Birch Cove area just outside of Halifax revealed that 68% of the 93 wells tested contained sodium and chloride levels greater than 20 mg/L and 50 mg/L respectively and that 14% contained chloride levels greater than the 250 mg/L guideline. In another study, eighteen of twenty seven salt storage depots across the province with their own well systems

were found to have salt contaminated wells (Cross, 1978a). One well contained chloride concentrations between 4550 - 8000 mg/L.

Each year the Dept. of the Environment investigates thirty to forty cases of wells contaminated by road salt - most of which have been referred by the Department of Transportation & Communications as part of their "Guidelines for Wells Affected by Salt Contamination". When road salting or salt storage has been identified as the probable cause of contamination, the Dept. of Transportation & Communications usually attempts to rectify the problem. Corrective measures include pumping the well to help flush the salt through the system, improving ditching and/or installing asphalt gutters to carry road run off away from the well, and switching to "sanding - only" for that area especially if several wells are affected. As a last resort a replacement well, usually a drilled well away from the road and with extra casing, is provided. Last year, the Dept. of Transportation & Communications spent over $300,000 on claims related to salt contaminated wells. This represents an increase over the past couple of years but remains about 1 - 2% of the total salting costs which have also increased.

5.2 Surface Water Contamination

Road salt has the potential for contaminating surface water by entering directly into rivers, streams, lakes, ponds and marshes as run off from roadsides and from salt and sand/salt stockpiles (Figure 7). The input of high concentrations of

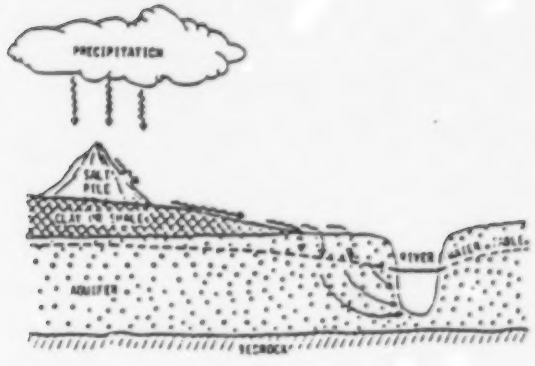


FIGURE 7: SURFACE WATER CONTAMINATION BY RUNOFF FROM A SALT PILE (after Walker and Wood, 1973).

chlorides disrupts the chemical balance of the aquatic system which may cause death to various freshwater biota depending on their resistance to such changes. Sodium has been found to increase the growth of blue-green algae, thereby stimulating nuisance algal blooms (Field et al., 1974). Another aspect of salt contamination of surface water environments is the release of mercury and other heavy metals from bottom sediments by sodium (Adams, 1973). The influx of road salt into rivers and streams during the spring are usually regulated by the corresponding increased volume of flow from spring time snowmelt. However, in other water bodies such as lakes, stratification by dense saline runoff water may prevent complete mixing and reoxygenation of the deeper levels of the lake and it becomes eutrophic.

In Nova Scotia, studies have been limited to a few small urban watersheds in Halifax County. A study of Chocolate Lake (Kelly et al., 1976) revealed a deep, saline layer of water, resulting primarily from highway deicing salt runoff within the watershed, which was preventing full vertical spring mixing. Salt intrusions into the lake amounted to over 120 tons in one year alone producing average sodium and chloride concentrations of 120 mg/L and 207 mg/L respectively. However, concentrations were consistently higher in the deeper regions of the lake reaching maximum concentrations of 206 mg/L and 330 mg/L. A similar study of the Williams Lake area (Underwood and Josselyn, 1979) concluded that salt concentrations were about ten times above what would normally be expected - the sole result of winter road salting.

An ongoing study of the effects of sodium chloride impacts on water quality of the Chain Lakes, which serve as back up water supplies for the Halifax Metropolitan area, was initiated in 1985 for the Halifax Water Commission (Hart, 1985, 1988). Average chloride concentrations have gradually increased since 1976 but have remained below the 250 mg/L drinking water guideline. The chloride concentrations show considerable fluctuation on a seasonal basis reaching a peak in early spring during the spring runoff period and dropping off in the summer with increased dilution and mixing (see Figure 8). Yearly and seasonal variations depend upon the amount of road salt applied during any given winter and the total amount of precipitation during the

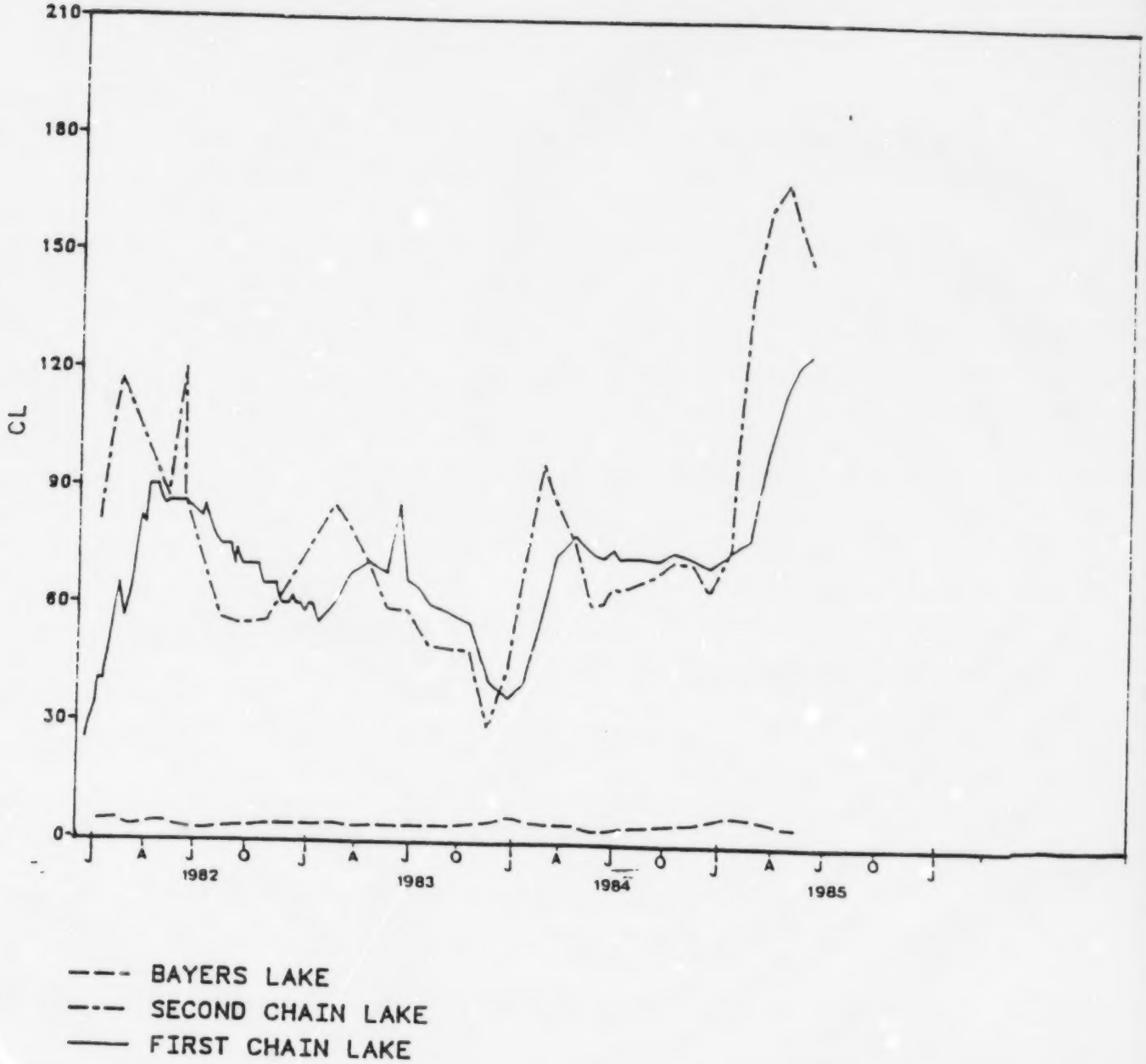


Figure 8: Whole-lake chloride concentrations for the Chain Lakes, Halifax County (after Hart, 1985).

winter and spring. It is interesting to note that a small stream in the vicinity of the Chain Lakes, located below a D.O.T. salt storage depot, shows consistently higher chloride levels - the maximum being 1960 mg/L in February, 1985.

While the extent of road salt contamination of Nova Scotia's lakes and rivers has not been studied in great detail, the above mentioned studies are probably typical of other urban watersheds across the province. A survey of base-line water chemistry from 234 Nova Scotian lakes (Underwood, 1986) showed the average background chloride concentration to be 8.1 mg/L. Since the average concentration of chloride in rainfall in Nova Scotia is only 2.7 mg/L (Underwood, 1988) and that most bedrock types in Nova Scotia represent only a small natural source of chlorides in surface waters (typically < 20 mg/L), water with chloride concentrations much above 25 mg/L or so must be receiving chloride inputs from other man-made sources. In watersheds with abundant roadways, road salting has to be considered a probable source.

5.3 Effects on Roadside Vegetation

Road salting can have damaging effects to crops, orchards, trees and other vegetation located near heavily salted roads. There are two types of problems arising from road salt: (1) salt which leaches through soil into the root system and (2) salt spray on above-ground plant parts. In the first case, road salt that has not been carried away by surface runoff or has not

seeped into the groundwater is retained in the soil by adsorption or ion exchange where it is available to the roots of plants and trees. In the second case, dissolved road salt becomes airborne by wind action or traffic movement where it forms a salt mist that may be intercepted by vegetation. Simini and Leone (1986) have suggested that salt spray is a more important cause of injury to roadside trees than salt in soil. Little evidence was found of sodium and chloride accumulation in soil beyond 30 m from the road however accumulation in plants were found as far as 120 m from the road.

Sodium in small amounts stimulates growth in many plant species but in large concentrations it is harmful to plants. Chloride is needed only in small amounts by plants as even low contents in plant tissue are potentially injurious and often lethal (Hanes et al., 1976). Road salt has three major effects on plant growth (Roth and Wall, 1976): (1) Salt alters osmotic pressure. Water is naturally attracted to salt concentrations, thus making it more difficult for plants to take in water by osmosis - the results being the same as plants experiencing drought conditions. (2) Increased salt applications result in higher accumulations of salt in plant tissues. (3) An ionic imbalance occurs. This accumulation of excessive chloride and sodium ions causes desiccation and leaf burn.

While the effects of road salting on roadside vegetation have been well documented by studies in the Northern U. S. and Canada, the problem appears to be limited in Nova Scotia. The

N.S. Dept. of Agriculture & Marketing receives very few complaints of soil and vegetation damage (Sangster, pers. comm., 1989). Only three incidents of salt damage to fruit orchards and one case of damage to low bush blueberries have been reported over the last five years. The effects noticed in the orchard damage included shoot tip die back, fruit bud injury and delay in bud development. Such incidents involved typically two to five acres damage at a cost of $1000 - $2000. In each case, damage was due to salt spray drift from the road.

5.4 Vehicle Corrosion

Road salt undoubtedly enhances the corrosion of vehicles. An American survey of 14,000 cars indicated that where little or no road salt was used, the chrome condition was judged good for 95.6% of the cars. In salt application regions, the percentage of cars with good chrome was only 80.4% (Struzeski, 1971). Another survey found that 58% of the cars examined in Detroit showed corrosion along chrome moldings while in Miami the same was true for only 35% of the cars.

There are other environmental causes of corrosion which must be considered including acid rain, salt-laden spray and mist in coastal regions, dust control chemicals used on dirt roads in summer and other airborne chemicals in combination with high humidity. Figure 9 shows the corrosion environment in the U.S. and Southern Canada from all causes. Vehicle corrosion is most severe however in the salt belt surrounding the Great Lakes and

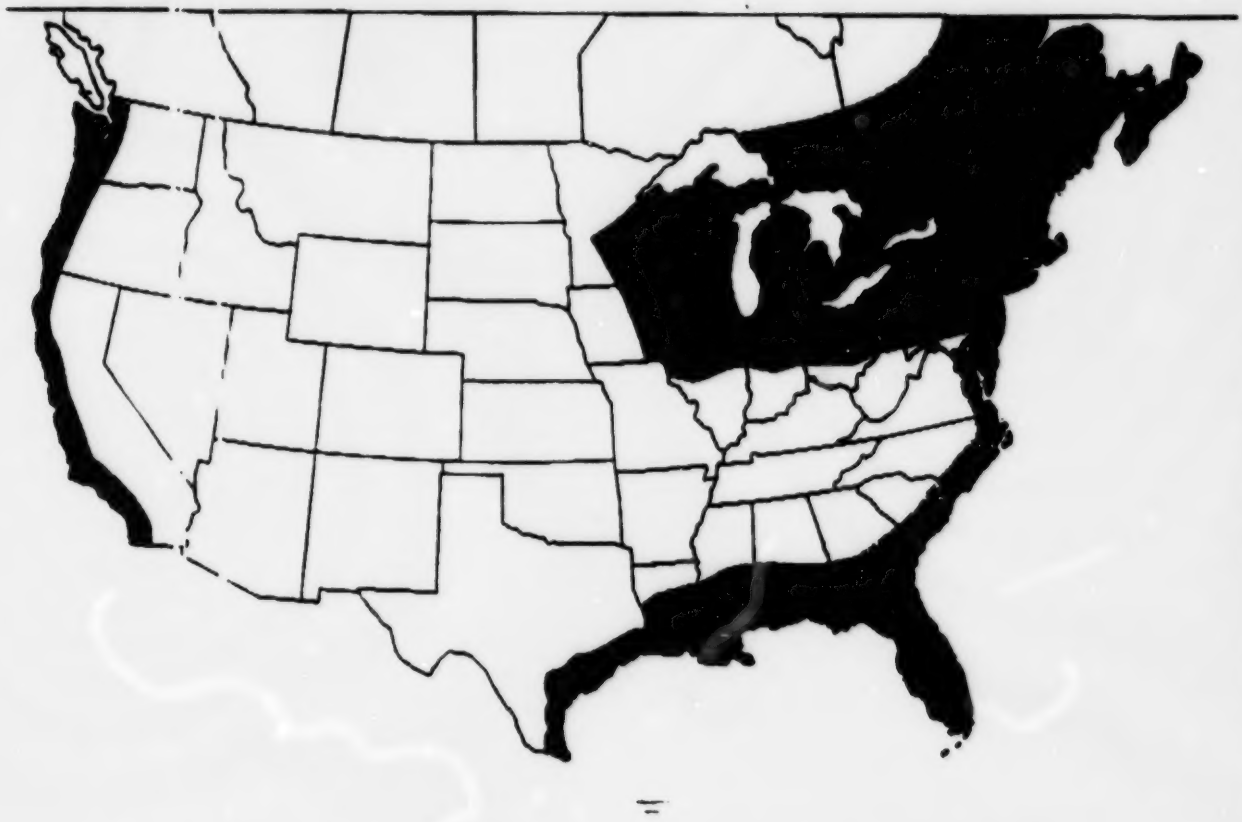


Figure 9: Corrosion environment in the U.S. and Southern Canada (after AISI report, 1985).

eastward through the northeastern U.S. and Ontario, Quebec and the Atlantic Provinces. Canadian studies have shown that corrosion rates were four times higher in humid, air polluted environments than in dry, nonpolluted environments with Toronto and Halifax listed as having the most severe conditions (Belangie, 1977).

Nova Scotia is quite vulnerable to vehicle corrosion with its humid climate, acid precipitation, salt-laden air due to its proximity to the ocean and the liberal use of deicing salts on its roads. Corrosion takes place when metals are exposed to oxygen in the air which, in the presence of water, produces iron oxide or rust. Salt water simply accelerates the process. Corrosion takes on many forms but the type accounting for about 90% of the damage to cars driven in the salt belt (AISI Report, 1985) is "inside-out" corrosion in which road debris accumulates on the underside and lower parts of the car body keeping the salt in intimate contact with the metal. Damage is extensive, expensive and usually undiscovered until perforation occurs.

But how do we put a price tag on vehicle corrosion damage caused by road salting? The Canadian study reported in Belangie (1977) showed that road salt and air pollution contributed equally to corrosion damage in the Toronto area. Belangie himself concluded that poor manufacturing methods in the automobile industry up until that time were as much to blame as anything on the corrosion problem. In an experiment designed to determine the relative effects of acid precipitation and road

salt on corrosion of automobile aluminum trim, Hayes and Baboian (1986) showed that while each had different effects the combination of the two produced the worst damage.

While efforts have been made to improve the corrosion resistance of today's vehicles, corrosion is still a multi-million dollar problem. Two separate studies of road salting costs in the U.S. have estimated vehicle corrosion damage costs to range from $643 million to $2 billion (Salt Institute, 1976). It was estimated that vehicle corrosion in the early 1970's was costing $100 U.S. per vehicle each year (Struzeski, 1971). In Ottawa, it has been estimated that vehicle depreciation due to corrosion by road salt costs individual car owners about $192 a year (Kelly, 1987). Thus it may be reasonable to assume that vehicle corrosion from road salting is costing Nova Scotia car owners about $200 a year in vehicle depreciation. In 1986-87 there were 337,000 cars registered in Nova Scotia (not including commercial vehicles, motorcycles and trailers) indicating a total cost of over $67 million for one year alone.

5.5 Effects on Roads, Bridges and Parking Garages

Another costly and widespread impact of road salting is damage to roads, bridges, parking garages and other reinforced concrete structures. Road salt causes concrete surfaces to scale and crack and steel reinforced concrete structures are subject to corrosion. Bridges are especially hard hit as road salting has been estimated to reduce bridge life from 20 to 5 years (Palmer,

1987). Road salt also contributes to the deterioration of asphalt pavements by keeping the pavement wet for long periods and allowing water in cracks and small openings to freeze and thaw in a cyclic manner with each application (OECD Report, 1972).

From a Canadian standpoint, structural damage by road salting is very costly. Bridge repairs in Ontario will cost an estimated $615 million while repairs needed for the Champlain Bridge in Montreal alone would run into millions of dollars (Spurgeon, 1989). Repair costs to two salt damaged parking garages in Ottawa amounted to about $8 million. Total repairs to all parking garages across Canada are estimated as costing up to $3 billion. In Nova Scotia, bridge repair costs due to all types of damage, including road salt, amount to over $1.9 million annually. These costs only represent about one-third of the total repairs that are required. In 1990, it is expected that two concrete bridges will be replaced on highway #104 due to road salt damage that is beyond repair. Parking garage damage does not appear to be significant as they are limited in number.

6. DISCUSSION

The use of road salt to keep our roads clear during the winter is taking its toll - on our health, on nature around us and on the pocket books of car owners and tax payers. While creating safe driving conditions, road salt also gets into the water we drink, alters the quality of our lakes and streams, affects the growth of roadside trees and plants, deteriorates our roads and bridges and causes our vehicles to rust quicker. Yet how does one compare these negative effects with the possible ramifications of not salting? The benefits of safe driving conditions and clear roads to keep our province moving probably far outweigh the costs associated with environmental impacts and damages to roads and vehicles.

A 1976 report by The Institute for Safety Analysis (TISA) on the benefits and costs of road salting (Salt Institute, 1976) estimated that the benefits outweighed the costs 18 to 1. The annual benefits, including economic benefits and energy savings not to mention lives saved in reduced traffic accidents and reduced response time to emergencies, amounted to about $18 billion. The total annual costs of road salting, including application costs, environmental impacts and repairs to roads and vehicles, were estimated to be just over $1 billion. An EPA study estimated the annual road salting costs to be much higher at almost $3 billion, but the benefit to cost ratio would still be 6 to 1.

Several alternatives to road salting have been tested and tried over the years by highway maintenance personnel but most have proved to be impractical or uneconomical. Calcium magnesium acetate (CMA) has received the most attention as a promising alternative deicer (Boice, 1985; Elliott and Linn, 1987; McElroy et al., 1988). Made from such materials as waste cellulose and limestone, CMA is less corrosive than sodium chloride and does not harm the environment. Although the pros and cons of CMA are still being studied, the main drawback remains its cost at approximately $1000/tonne. In Nova Scotia, the only alternative used to "straight" salting is the use of sand which contains 5 - 10% salt. Salt/sand mixtures are only used in areas designated as being "environmentally sensitive".

Since sodium chloride appears to be the most effective and economical means for road deicing, attention needs to be given to minimizing the use of salt and improving storage and handling practices. The prevailing theme of the sensible salting concept is to use the minimum amount of salt necessary to achieve the desired effect. This will involve among other things: (1) calibration of ground-speed controlled spreaders so that the proper application rates will be followed and excess salt will not be spread when the salt truck is stopped or moving slowly (2) strict adherence to ice control and sanding policies (3) spreading of salt in windrows in the centre of the highway (4) accurate weather forecasts geared to road conditions so the salt can be applied early (5) greater reliance on plowing to keep the

roads bare rather than excessive salting (6) timely repairs to cracked and rough pavements which are difficult to plow and require additional amounts of salt to achieve bare pavement (7) better accounting of the amounts of chemical used and (8) greater awareness of the environmental impacts of road salt and the associated costs. Ultimately, the responsibility belongs with the individual operators and it is there that the lessons need to be learned. The Maine Dept. of Transportation was able to reduce its use of salt by 42% over a ten year period by using intensive training sessions and calibrated salt-spreading equipment (Boice, 1985).

The other area where improvements are needed is in the storage and handling of material. Salt-laden runoff from storage facilities for salt and sand/salt mixtures is one of the prime causes of surface and groundwater contamination. While most salt piles are now placed on an impermeable base and housed indoors, the majority of sand/salt piles are left out in the open. A recent New Brunswick study showed that a "sand" pile mixed with 2.5% salt could lose 50% or more of the salt by leaching and chloride concentrations up to 82,000 mg/L (i.e. 3× greater than sea water) were found in the leachate at the edge of the site (Cross, 1978a). Sloppy loading and mixing practices in the storage yard are also responsible for causing contamination as spillage from overloaded trucks and from the buckets of front end loaders when loading and mixing, often remain untouched.

Road salting will always be a delicate issue. The four objectives involved with road salting, namely health and safety, environmental protection, energy conservation and economics, will always be at cross purposes with each other. Right now, driving safety and economics appear to have the upperhand. However, the environmental implications of road salting could become severe and have long reaching effects. For example, if 18% of adult Canadians suffer from hypertension and possibly 50% of the wells along salted roads contain sodium levels greater than those recommended for low-sodium diets, then a serious problem may be developing in the long term. Clearly, a balance needs to be struck when deciding how much salt is enough. The public needs to be made aware of some of the harmful side effects of road salting and possibly change its attitudes and expectations towards winter driving. The Departments of Transportation and Environment need to ensure that proper policies are developed and adhered to. One thing is for certain, winter snow and ice will always cause problems with driving conditions. Only by working together will the problem be solved.

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